

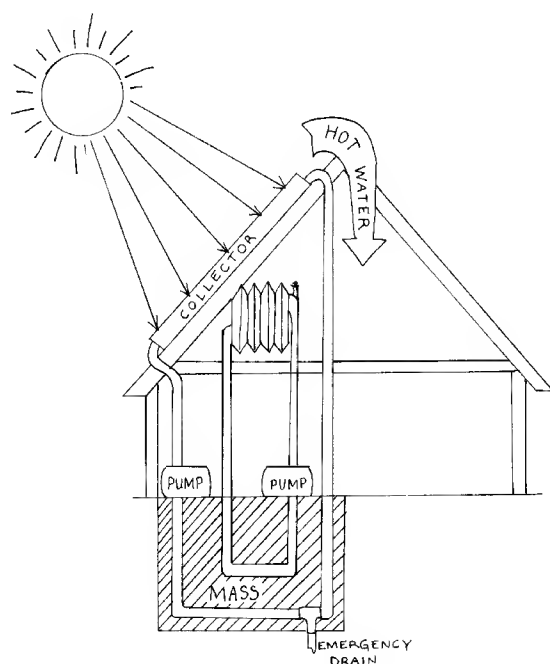
Designing for solar heating

By Don Fallick

How you plan for solar heating depends to a very great extent on whether you're building a new structure or adding on to an existing one, and on the method of heat transference. It might be said that these considerations loom so large as to virtually determine the design of the system.

Active systems

So-called "active" solar heating systems produce the highest temperatures. Their liquid heat-transfer fluids lend themselves best to integration with a conventional heating system. They are relatively easy to retro-fit to an existing structure, are not especially bulky, allow for traditional architecture, and can be modified, enlarged, or even removed, at any time. They also require expert installation, and are inordinately expensive to purchase, run, and repair.



Active system

"Active" disadvantages

Virtually all active systems require electricity to run pumps and controllers. Protection must be provided to guard against freezing of the circulating water, or to ensure that poisonous anti-freeze solutions remain isolated from the environment. Protection must be "fail-safe" against power outages during severe winter weather. Lots of systems failed in Seattle, Washington, in 1991 when a coastal city that rarely sees any snow caught over two feet in 24 hours. Much of the city was without power for several days during the coldest Christmas on record. Provision must also be made for emergencies caused by the failure of these "fail-safe" systems.

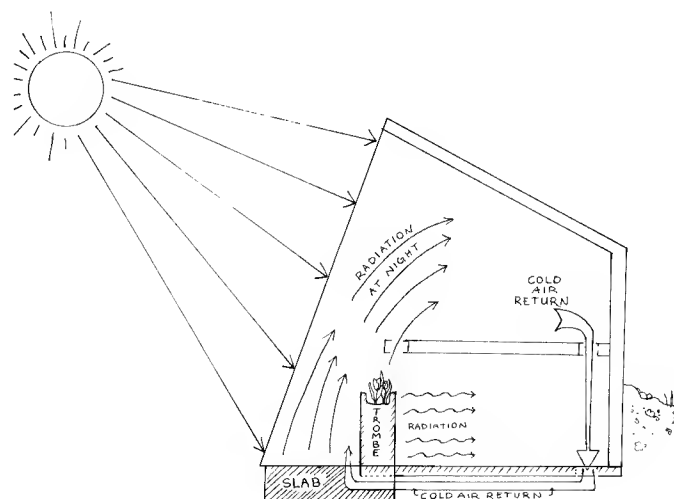
Active systems require direct sunlight to function, so there must be some way to store heat during cloudy periods as well as at night, and to recover the stored energy. All these requirements increase the cost of the system while decreasing its efficiency.

The trade-off between reliability, cost, and efficiency has led many solar designers away from "active" systems, especially when designing for new construction.

Passive systems

Besides allowing a wider choice of building sites and orientations, new construction facilitates design of passive solar heat systems, which use sunlight to directly heat the building itself, or the air within it. Passive systems depend upon *convection* or *radiation* to circulate the collected heat. While some "passive solar" homes do use fans to assist circulation, most can function, at least minimally, without electricity.

Because they do not need to heat a liquid up to near boiling, passive systems are good at extracting useful energy from even diffuse sunlight. If your area is frequently overcast in winter, a passive, warm-air system may be your only solar option. Many solar "experts" who make a living selling active systems refuse to acknowledge how much energy such a system can extract from a theoretically "impossible" situation. (See "A house heating solar greenhouse" in *BHM* # 12.)



Passive system

"Passive" disadvantages

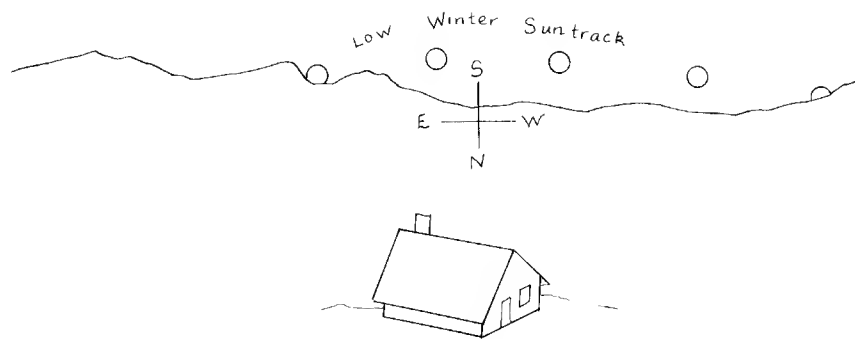
The disadvantages of passive solar stem from the same qualities as its advantages. Because passive systems operate on small temperature differentials, they require excellent insulation to retain those "extra" degrees of heat. Often, such houses are earth-bermed, or even built underground, to take advantage of insulation which is literally "dirt cheap." Because the house or the air is heated directly, the system must be built into the building, or at least be a major architectural addition.

The large areas of glass needed to capture diffuse sunlight make it impossible to disguise the nature of a passive solar heating system. Regardless of one's preferences in architecture, or the actual design, passive solar homes come in only one basic style. Worse, those large glazed areas can turn the building into an inferno in the summer unless provision is made for shading and ventilation.

To prevent nighttime heat loss, glazed areas must be covered with insulating shutters or blinds. Opening and closing shutters requires tedious daily attention. Owners of passive solar homes dare not leave them unattended more than a day or two. Many ingenious systems have been invented to solve this problem, and some work fairly well, but all complicate the system, add to its cost and upkeep, and detract from its efficiency.

Glazing

Glazing is indeed the weak point in a passive solar design. Many companies have introduced so-called "solar" plastics, designed not to cloud up, even after decades in direct sunlight. I know of none that actually delivers as promised. Those that come close have shown tendencies to weaken and weather. The only thing that really works right is tempered glass, which is heavy, fragile, expensive, and hard to seal permanently. **Do not use ordi-**



*Taking advantage of a low spot on the horizon
by orienting away from true south*

nary window glass, which becomes deadly when shattered. Tempered glass isn't much stronger than window glass, but it breaks into rounded pieces or powder, instead of deadly, pointed missiles.

One of the most important advantages of passive designs is that they tend to use "low technology." If you're capable of designing and building a "normal" structure, you can probably do just as well designing and building your own passive solar home.

No free lunch

All solar heated designs must include provision for a backup heating system, for those periods when *insolation* (incoming sun energy) just isn't enough to overcome weather of extreme severity or duration. There are no 100% solar heated homes. How

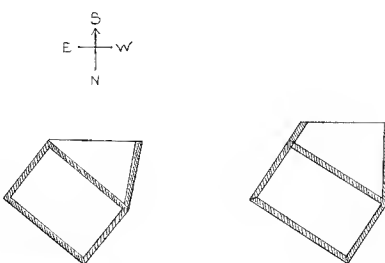
close you come to 100% will depend on how much time, money, and expertise you have available to put into the project, as well as the weather.

There's no free lunch. A solar assisted home is one which receives less than 50% of its heat from the sun. The less you depend on your solar system, the cheaper and easier it will be to build.

An example

The house heating solar greenhouse mentioned earlier provided about 75% of our heat, at a cost of about \$1000, including the use of lots of recycled materials and **no** hired labor. Convective distribution of heated air was assisted by floor grates, costing nothing. (See "Heat your upstairs by cutting holes in the floor," *BHM* #14.) These additions, plus a **lot** of insulation, helped convert a cold, drafty, century-old house into a fuel miser that used only one cord of hardwood to get through a bitter Wisconsin winter! We could have increased our "solar percentage," but the cost would have far exceeded the return in saved energy!

There are many contractors who will install a prefab "solarium" for you, usually for a stiff fee. These range from really good ones to strictly decorative units that leak more heat than they produce. One of the best national brands is sold by Four Seasons. They



*Two ways to add a south-facing
greenhouse to a non-south-facing
structure*

work, they don't leak water or heat, and they're guaranteed. They're not cheap, though.

Doing it yourself

The weak point of virtually all do-it-yourself greenhouses is sealing the roof glazing panels. "Sunlite" solar plastic by Kalwall is still the best solution, in my book. It will eventually degrade and need replacement—in 10 to 15 years. It costs nearly as much as glass. But you can get it in rolls, and stretch a single sheet over a 2 x 2 support grid, sealing it down with silicone seal and gasketed roofing nails. It's picky work getting it on right, but not difficult, and it leaves a glazed roof that can't leak, except at the edges. These can be sealed just like any glazing. The plastic is nearly 1/8" thick, lasts much longer than the corrugated stuff most of us are familiar with, and looks lots better.

Existing structures

Solar additions to existing structures can be practical, even if there is no south-facing wall to attach them to. The greenhouse need not be built parallel to the building wall. A triangular or irregular plan can work just as well as a rectangular one, as long as the ratio of the greenhouse volume to glazed area is kept around 9:1, plus or

minus a bit. In my experience, ratios higher than 10:1 won't provide enough heat to justify the expense and trouble of construction, while ratios lower than 8:1 will be difficult to insulate at night.

Other orientation

It may not be necessary to orient the glass to face due south anyway. Generally, solar heating systems work best with a maximum southern exposure to the sun, but there are exceptions.

When the sun is low in the sky, the earth's atmosphere filters out much of its heat energy. That's one reason why it's hotter at noon than in the morning or the evening. Near the US/Canadian border, the winter sun is close to the horizon *all* the time, so there is less reason to prefer noonday sunlight. It may be possible to increase the total duration of direct "insolation" by orienting the building slightly away from due south, taking advantage of low spots in the horizon.

My house in Washington State did just this. (See *BHM, The Best of the First Two Years*: "Semi-underground, solar house has some ideas worth crowing about.") High canyon walls would have blocked the low winter sun, but the house was oriented to take advantage of a rift in the canyon rim,

giving a boost to the total insolation, just when it was needed most.

The only way to tell if such "mis-orientation" will help is to compare suntrack charts for all sites under consideration.

Sky heat

Depending on your intended use, you may wish to orient a passive solar collector to take advantage of either morning or afternoon sun. "Sky heat," which is the primary source of the energy collected by warm air systems, is greatest in the afternoon, when the earth is re-radiating the solar energy it has soaked up in the daytime. Greenhouses intended primarily for house heating should be oriented to take advantage of sky heat, as well as the more direct sunlight around noon.

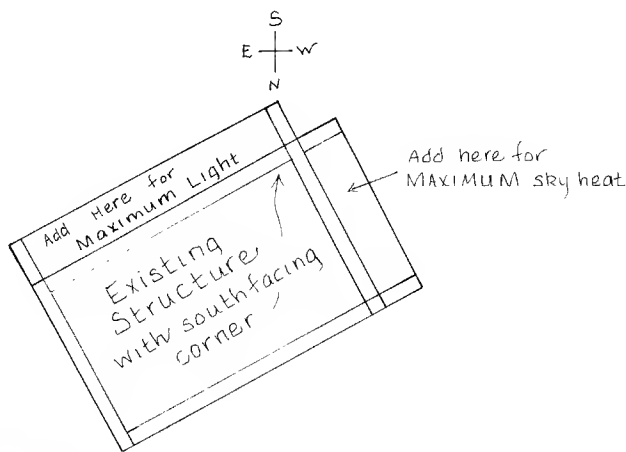
Sky heat may not be necessary for greenhouses intended primarily for raising plants. Seedlings need long hours of light. Heating them is secondary. In fact, a greenhouse optimized for heat may get too hot for raising plants, and require venting to keep from killing them!

Vertical glazed walls

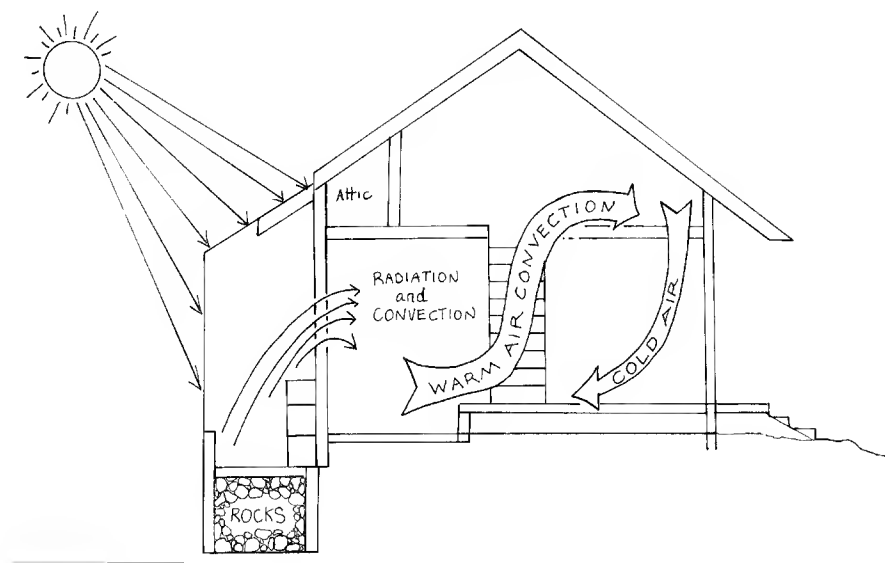
It's easiest to build vents into vertical walls. Everybody "knows" that solar glazing is supposed to be angled to catch the sun as directly as possible. The angle usually recommended is equal to 90° minus the latitude of the site. For the continental US, this results in a glazed wall between 65° and 45°. Such walls are difficult to build, glaze, seal, insulate, and ventilate.

Fortunately, studies have shown that an identically glazed vertical wall loses only about 5% to 10% of its heat-gathering ability. Improved ability to shutter or otherwise insulate a vertical wall against nighttime heat loss may more than make up for the slight loss in heating efficiency.

But the real plus for vertical walls is their greater ease of ventilation.



Designing for maximum light vs. maximum sky heat



The author's solar-heated house in Wisconsin

Screens, window cranks, and other technology are readily available and cheap. If you make most of your main glazing openable, you may not need any other vents. If you can't do this, as a rough rule of thumb, you'll need a ratio of about one square foot of vent to nine or ten square feet of glazing.

Vents should be placed so as to create a cross draft, with low vents facing the prevailing wind, and high vents on the downwind side. Greenhouse suppliers sell heat-operated, non-electric vent operators. I've seen them in use, and they work well and last forever. Check with your supplier before designing your vents, as they have weight limits.

Convection

Hot air rises. This is the basic principle behind convective heat distribution. If you can make the solarium the lowest part of the structure, with gradually rising living areas, natural convection will tend to distribute warm air from your passive collector without any other assistance.

However, you must also design in a way for the cooler air to return to the collector for reheating. In our house in Wisconsin, warm air from the collec-

tor flowed through the kitchen/dining room, up a step to the living room, then up the stairs to the bedrooms. The final bedroom had a floor register which allowed the relatively cool air to descend to the living room floor, where it was sucked across the kitchen floor and back into the collector. It did create a relatively cool draft across the floor, but the temperature differential was only about 10° F, so it wasn't unpleasant.

Convective solar additions frequently have problems like this, but designers of new structures can plan for convection to eliminate winter floor drafts.

Thermal mass

Solar heating systems are cyclic. They gather heat in the daytime, but use it primarily at night. To bridge the gap, there must be some way to store excess heat and distribute it later. Many methods have been tried, but all work on the same principle: moving a fluid such as air or water past a previously heated thermal mass, or *heat sink*. The mass adds inertia to the system, soaking up energy during the day and radiating it slowly at night.

Thermal mass can take many forms, but there are only two ways to get the heat energy into it. Active systems circulate high temperature liquids through or around the storage medium, heating it up. Because the storage mass is relatively small, it must be heated quite hot to retain enough energy to last the night. Heat transfers only from a relatively hotter medium to a relatively cooler one, so the liquid must be very hot indeed for the process to work. This is the source of all the problems with active systems.

Passive systems use a slightly different system. Instead of heating up a fluid and using it to transfer heat to the storage mass, they use sunlight to heat up the mass directly. If the mass is just large enough, it will hold just enough energy to radiate all night long, returning to its original temperature by morning. If the mass is too small, it won't hold enough energy to last all night. If it's too big, the mass will require more hours than there are in the day to reach the proper temperature. In other words, it will never get warm enough to function properly. Fortunately, a lot of mass is required to heat a whole house by radiation, so it's hard to build in too much.

The ideal place to put thermal mass is just inside the glazed area. Thick, concrete slab floors make excellent thermal mass, but must be well insulated from the cold earth beneath. They should be painted dark colors for heat absorption, or decorated with dark rock slabs, set well into the concrete for good conductance of heat.

Trombe walls

One way to add **lots** of thermal mass (without the disadvantages of concrete floors—see below) is to build in a short, **very** thick partial wall between the solarium and the rest of the house. This is called a *Trombe* (rhymes with "bomb") *wall*. It soaks up heat directly from the sun shining on it during the day and re-radiates it into the house at night.

Trombe walls are usually painted dark on the collector side, but may be any color desired on the radiation side. They are frequently covered with brick, to add yet more thermal mass, beauty, and additional radiation surface. Often there is a brick-enclosed planter on the wide top of the trombe wall. The earth provides yet more thermal mass, and the houseplants grown there disguise the solid nature of the Trombe.

The water Trombe

Concrete has two great disadvantages as thermal mass. It's very expensive in the quantities needed, and it's virtually impossible to add or subtract mass after it sets. Ken Kern, author of The Owner Built Home, invented the "water Trombe" to solve these problems.

A water Trombe is a wall consisting of stacked steel water barrels. Since water is only half as dense as concrete, a water Trombe needs to be about twice as thick as a concrete Trombe wall. This can be easily accomplished by stacking the barrels horizontally, on their sides, with one end facing the collector and the other facing into the house. Only the collector ends need be painted black.

Caution! A drum full of water weighs about 460 pounds. If you build a water trombe, **be sure** you build a rack that is strong enough to hold the weight. A 25-foot Trombe wall with barrels stacked in two layers weighs close to **five tons**. Be sure your foundation and footings are up to it. Because of these weight considerations, a Trombe wall of any kind is not something you can easily retrofit after the building is built. It is possible in some cases, but I wouldn't recommend it without the services of a competent architect. D